Photonic Snake States

RESEARCHERS

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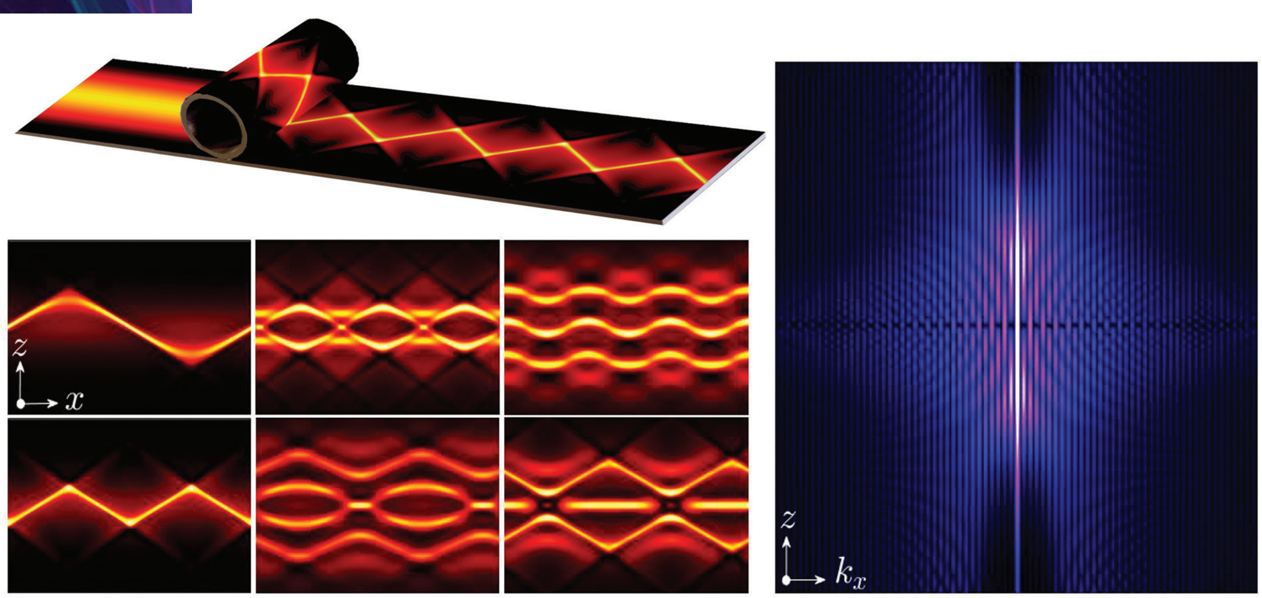
Half a century ago, scientists predicted that universal, transverse snake instabilities[1] strongly distorted nonlinear waves in a wide variety of multidimensional nonlinear systems. Since then, such phenomena have generally been viewed as highly destructive over all the different domains of nonlinear science. However, in recent work, we showed that such instabilities can be tamed in suitable optical cylindrical microcavities.[2] Although the snake instability typically leads to transient zigzag patterns, we discovered that in suitable microcavities, the pronounced zigzag spatiotemporal waves appear as stationary states, which we have named photonic snakes.

Remarkably, such states are stable and robust against perturbations that arise due to realistic dispersion, heating and Raman scattering, among other factors. They also generate 2D frequency combs that are spatially sparse (along the cylinder's axis) and intrinsically synchronized by the nonlinearity, forming in a single monolithic microcavity. Notably, photonic snake states may be deterministically excited or reshaped, and they exist in the normal dispersion regime. Thus they are able to extend comb formation into the ultraviolet and infrared spectral regions, where anomalous dispersion is typically not available. The potential for multicomb hosting of microcylinders extends well beyond single-snake states, as we have also found multiphotonic snake states.[2]

Optical frequency combs emerged in the late 1990s as ultra-precise measuring tools that revolutionized many research fields, such as metrology and spectroscopy.[3] Integration of stabilized microcombs[4] has since constituted one of the main aims in the area. Recently, crucial steps toward achieving deterministic excitation of combs[5] further improved the suitability of microcombs for applications in photonics.[3] Our new photonic snake states have been shown to intrinsically display all the above required features without needing complex setups due to their multidimensional nature. They thus constitute a new paradigm for the creation of robust frequency combs. OPN



Top left: CW-driven cylindrical microresonator in the photonic snake regime coupled to a slab waveguide serving simultaneously as drive (left) and collection (right) ports. Bottom left: Examples of photonic snakes. Right: 2D frequency comb carried by the photonic snake state in upper-left example. z is parallel to the cylinder's axis, x is the periodic coordinate along the cylinder's circumference, and k_x is the wavenumber. The comb is symmetric with respect to the laser's wavenumber.

REFERENCES

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